Goleta Bay Sand-Based Kelp Bed Reestablishment

For Mitigation of Shoreline Erosion and Enhancement of the Marine Ecosystem

Draft
Proposal

By

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Introduction:

In February 2003, I submitted a hypothesis to various individuals involved with addressing the erosion problem of Goleta Beach. This hypothesis centered on the idea that there is a correlation between the kelp bed off-shore and the size of the beach. I have researched this relationship further and developed a strategy for testing the hypothesis. If my proposal is successful, it could provide a long-term solution to the erosion problem at Goleta Bay.

My proposal focuses on recreating the conditions that had favorable results prior to 1982 with regards to shoreline processes and the influence they had on the formation and sustainment of a wide beach.

I have made many inquiries of ocean engineers, oceanographers, geologists, marine biologists and an assortment of other people; many of whom are familiar with the Goleta Beach erosion problem. Their positive responses to my conceptual plan have assured me there is probable cause and justification to pursue this idea further.

I frequented Goleta Beach often as a child (since 1961) and have continued to make regular visits to the beach during visits back home. My interactions with this beach (and others) have helped me develop an awareness of cause-effect relationships and shoreline processes that have resulted in changes to the beach.

The purpose of this paper is to summarize my findings to date and present possible underlying circumstances associated with the Goleta Beach erosion problem in order to build a case for the pursuit of further study and experimentation.

Historical Observations:

For several decades prior to 1982, a wide beach inside of Goleta Bay coincided with the existence of a very large, well-established kelp bed off-shore (Figure 1). The kelp was dislodged by unusually large swells associated with storms during the 1982-83 El-Niño event. Over the last twenty-plus years, narrowing of Goleta Beach has occurred and the kelp bed off-shore has not recovered (Figure 2).

Figure 1.
Goleta Bay, 1972. Well established kelp bed and coinciding wide beach. Tracks through the kelp bed are from kelp harvesting operations.
Pacific Western Aerial Surveys

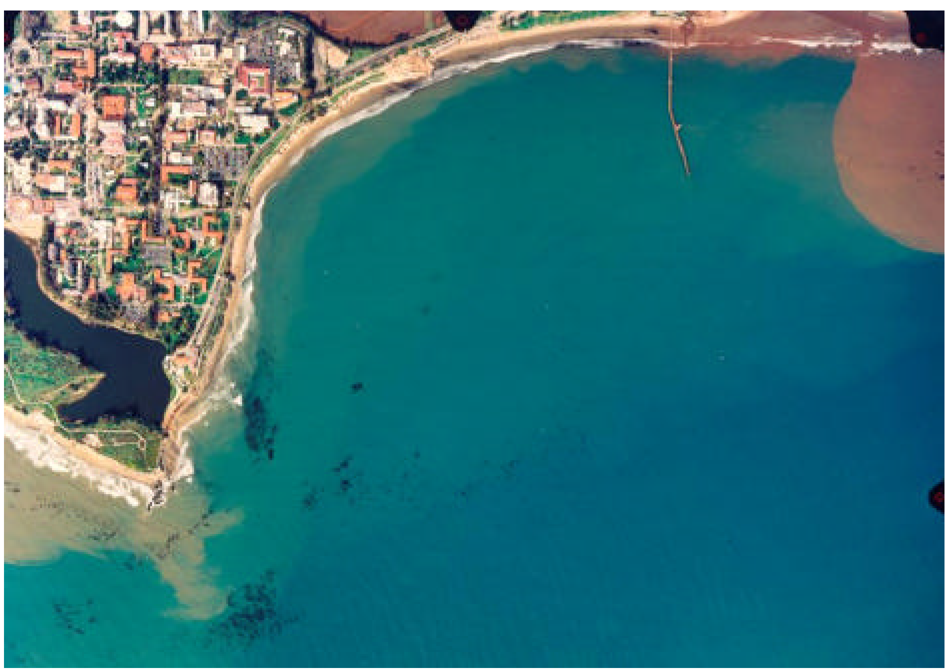

Figure 2.
Goleta Bay, 1992. Absence of large kelp bed and coinciding narrow beach. Silt plumes are from storm runoff.
Pacific Western Aerial Surveys

Questions:

1. Did the wide beach and large kelp bed coexist prior to 1982 because conditions were favorable to the formation of both?

   Or

2. Did the kelp bed contribute to the formation of a wide beach?

3. Why has the beach continued to narrow over the last twenty-plus years?

4. Why hasn't the kelp bed reestablished itself since its disappearance over twenty years ago?

5. Would reestablishment of the kelp bed aid in the natural recovery of a wide beach and if so, how long would it take?

6. Has there been a reduction in the delivery of sand to the coast since 1982?

   Or

7. Has there been a redistribution of sand along the shoreline since 1982 resulting in narrowing of the beaches?

Answers to these questions should be sought in order to develop an ecologically-sound strategy for resolving the erosion problem of Goleta Beach.

Shoreline and Coastal Processes:

The dynamics of shoreline processes are complex, variable, ever changing, often unique to a given area, and difficult to quantify.

Storms, although infrequent, have the potential to alter the shape and appearance of the shoreline in a dramatic fashion. Seasonal storm activity and high tides during the winter months generally result in narrowing of the coastal beaches. Smaller waves associated with the spring, summer and fall months often reverse the erosion process by redepositing sand from off-shore, back onto the beach. This seasonal cyclic process of beach build-up and tear down rejuvenates beaches through the sorting and redistribution of the sediments. The formation of a wide beach protects the backshore beach from exposure to the erosive effects of storm activity by acting as a renewable buffer. Widening of the beach through natural processes would be preferred over the more invasive and costly methods of dumping fill, dredging and beach nourishment.

In the several decades prior to 1982, equilibrium between shoreline processes influenced the formation and sustainment of a wide beach inside of Goleta Bay (Figure 3). Despite the lack of any major change in the tides or weather in the last two decades, a new equilibrium in shoreline processes has resulted in narrowing of the beach (Figure 4).

Figure 3.
View from Campus Beach (University of California Santa Barbara - UCSB) looking toward Goleta Beach, 1975. Vegetation along the backshore area is indicative of a relatively stable beach.
Arthur Gibbs Sylvester, UCSB

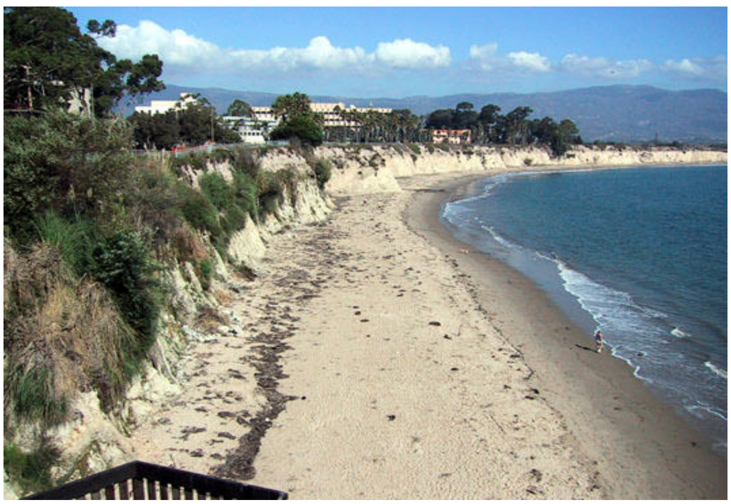

Figure 4.
View from Campus Beach (UCSB) looking toward Goleta Beach, 2001. Vegetation has not recovered along the backshore area since its removal by storm activity in 1982-83 and a relatively narrow beach has persisted.
Arthur Gibbs Sylvester, UCSB

Possible Kelp Bed Influence:

The idea of kelp bed reestablishment as a means of mitigating the erosion problem of Goleta Beach was rejected by the planning committee (Goleta Beach Master Planning Process) on the basis that kelp beds have little known effect on the attenuation, deflection or refraction of large, low-frequency gravity swells. Nonetheless, kelp beds are effective at altering higher-frequency, wind-generated capillary waves and currents. Although subtle, these are the forces at work on the shoreline the vast majority of the time.

Beach sediments that are put into suspension by the turbulence associated with breaking waves are made available for transport by currents. Wind-generated currents acting on the shoreline can result in the seaward and/or alongshore migration of sediment. In localities where the current is subdued, sediment is deposited onto the beach by wave action and the beach is widened over time. Due to the immense size of the kelp bed that existed off-shore of Goleta Bay prior to 1982, it is likely that it influenced the wind-generated coastal currents in such a manner as to favor the formation of a wide beach.

Kelp Bed Establishment Prior to 1982:

Macrocystis kelp has been successful at establishing itself along vast stretches of sandy substrate off-shore of the Santa Barbara Channel coastline. Prior to 1982, the kelp bed stretched along the Santa Barbara Channel coastline in an almost continuous band.

Conditions are favorable for the growth of kelp along the California coastline the majority of the time. Periodic ocean conditions resulting in low nutrients and high water temperatures are short lived and the physical condition of the kelp tends to recover in a relatively short period of time once normal conditions return.

The geography of the region plays a significant role in the ability of sand-based kelp beds to become established. The east-west orientation of the coastline and the existence of the Channel Islands off-shore provide protection of the shoreline from swells.

The tenuous anchoring system of juvenile kelp plants on sandy substrate requires very mild conditions for an extended period of time to allow the holdfast to grow large enough in order to develop an effective anchor. Subsequent generations of kelp plants recruiting onto the holdfasts of older plants build up the anchoring system. Eventually the holdfast becomes large enough that it can sustain occasional moderate swell activity.

As the density and width of the kelp beds grow, so does their influence on shoreline processes that shape the beaches. In the several decades prior to 1982, the establishment of sand-based kelp beds along the Santa Barbara Channel coincided with the formation and sustainment of significantly wider beaches than are seen today along many areas of the coastline.

Difficulty of Sand-Based Kelp Beds to Recover Naturally:

Severe storm swell activity associated with the 1982-83 El Niño event dislodged virtually all the kelp plants from the rocky reefs and the sandy stretches off-shore of the coastline where they thrived for decades. This sudden massive loss of potential spores resulted in slow recovery of the kelp beds. As I recall, it was a couple years before kelp canopies could be seen off-shore of the coastline and these were only in areas where rocky reef substrate exists. The natural rocky reefs however, comprise a very small percentage of the off-shore substrate. The delicate anchoring system of the kelp plants growing on sandy substrate makes them susceptible to being easily dislodged, and for the most part, have failed to recover to date.

During a visit to Goleta Beach in August of this year, I found numerous young kelp plants on the beach that yielded a clue to what the plants off-shore were recruiting onto. Virtually all the holdfasts of plants that had attempted to grow on the sand contained a single piece of parchment-like worm tube from the worm *Diopatra ornata* (Figure 5).

Figure 5.
Underside of juvenile *Macrocystis* holdfast revealing piece of worm tube used as attachment source. The size of this kelp plant and the piece of worm tube present under the holdfast was typical of numerous plants found on the beach in August 2003.
Greg Christman, August 2003

While SCUBA diving off-shore of Goleta Bay, I found an abundance of the worm tubes and numerous young kelp plants. Close examination of the holdfast of each young kelp plant revealed the worm tube used as the recruitment source. The haptera (root-like projections) of each holdfast spread out over the sea floor, attempting to anchor the plant to the sand.

In the sandy regions off-shore, the worm tubes are for the most part the only surfaces abundant and stable enough for kelp plants to recruit onto. It is the fragile nature of this attachment source, coupled with the sandy substrate upon which to grow, that appears to prevent the juvenile kelp plants from growing to maturity.

The inherent buoyancy of the kelp plant increases as the growth of the stipe (stem) and pneumatocysts (gas-filled bladders) at the base of each (non-spore producing) blade progresses. As the plant grows upwards towards the surface, the buoyancy and drag created by the plant starts to exceed the holding capability of the holdfast on the sand. The plant eventually pulls up away from the sand, tearing off a piece of its worm tube host as the young plant is sent adrift (Figures 6 &7).

Figure 6.
Juvenile *Macrocystis* kelp plant. Note underside of holdfast with piece of worm tube (used as attachment source), stipes, pneumatocysts, blades and Sporophylls (spore producing blades, without pneumatocysts, near base of kelp plant).
Robert Kiel, August 2003

Figure 7.
Kelp detritus on beach. Note holdfast in center of picture (highlighted) with long piece of worm tube. Also, similar size of the holdfasts indicates plants are from the same generation.
Robert Kiel, August, 2003

Optimal Zone of Sand-Based Kelp Beds:

The optimal zone in each area for the natural recruitment and growth of kelp is apparent by observing the well-defined boundaries of the surface canopy (Figure 8).

The ratio of plant size and growth rate to holdfast size and growth rate is a likely factor in establishing the outer boundary of the sand-based kelp beds. Kelp plants along the coast will grow to depths of seventy feet or more in areas containing solid substrate, where sunlight penetration appears to be the limiting factor. Along adjacent sandy stretches, the kelp plants seem to have a maximum depth range of about fifty feet. Beyond this depth, it is likely that the plants reach a critical size relative to the holding capability of the plants on the sand.

The inner boundary of the sand-based kelp beds, although less defined but still apparent, is likely due to the depth at which large swells start to touch the bottom. Even a well-established holdfast simply reaches a point where the surge created by large swells tears out the plant. Juvenile plants growing on sandy substrate at depths less than about thirty feet deep will be subjected to high surge from large swells each year resulting in their dislodgement.

Dredging of sand for beach nourishment from the area inside the optimal zone for the growth of sand-based kelp beds (Figure 8) could be considered as a means to expedite widening of the beach. Concerns about disturbing young kelp plants attempting to grow in this periodically turbulent zone are moot since the plants will ultimately succumb to dislodgement by seasonal swells.

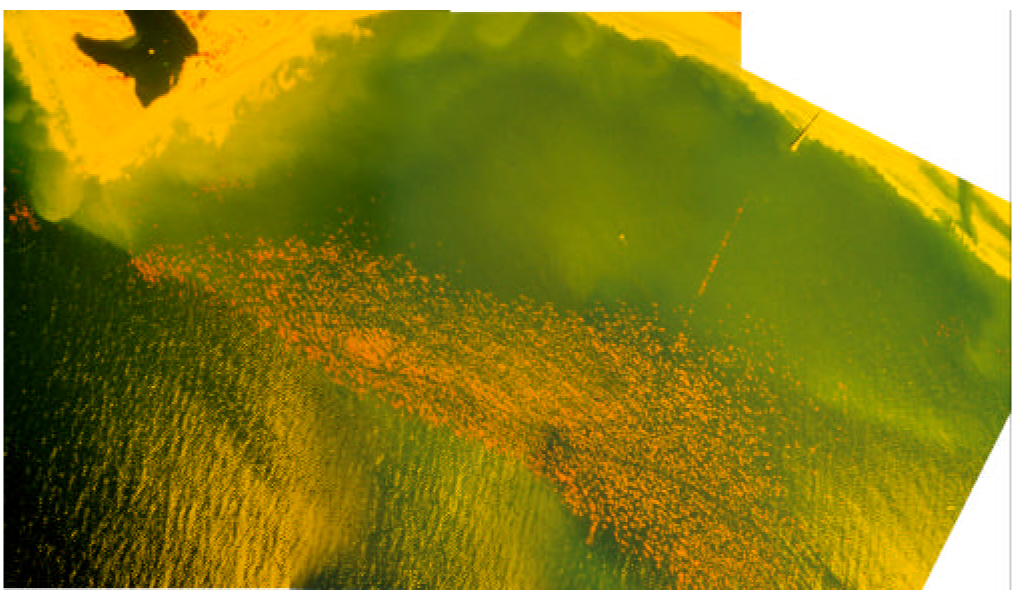

Figure 8.
This series of aerial photos spliced together shows the well-established kelp bed off Goleta Bay in 1979. The pictures were taken by ISP Alginates (formerly Kelco) to document the condition of kelp bed #26. The well defined boundaries of the kelp bed are apparent, revealing the optimal zone for the growth of the sand-based kelp bed. The track running lengthwise through the kelp bed is from kelp harvesting operations. The single line of kelp indicates the location of the treatment-plant outflow pipe. Note how kelp growing on more solid substrate (e.g., outflow pipe) grows outside and inside the primary zone of the sand-based kelp bed.
Picture editing by Greg Christman

The presence of the worm tubes of *Diopatra ornata*, combined with years of mild swell activity is likely to be the underlying factors for the past establishment of sand-based kelp beds. Unless conditions are optimal for an extended period of time, regeneration of the sand-based kelp beds (to pre-1982 conditions) through natural processes is unlikely. Even if reestablishment of the kelp beds should occur, they remain vulnerable to becoming dislodged during future storm activity. Reinforcing sand-based kelp beds by providing a ballasted anchor upon which to grow will increase the kelp plants ability to withstand storms and help ensure their long-term survival.

Conceptual Strategy for Reestablishing Sand-Based Kelp Beds:

Since January 2003, I have conceptualized and examined various options for suitable anchor systems upon which to grow kelp. There are different methods available that would likely work but most have inherent problems associated with them. In order to maximize the likelihood for long-term success, the following criteria must be met when considering a kelp anchor design:

- Feasibility: It has to be "do-able" on a large scale.
- Cost: The cost must be minimal in both materials and labor.
- Toxicity: Materials must be innocuous and harmless to marine life and the environment.
- Longevity: Materials must be long lasting (one hundred years or more).
- Deployment: The anchor system must be capable of being tossed over the side of a vessel and must land upright on the sea floor, without the need for diver assistance or underwater machinery.
- Location: Anchors should be placed in the zone off-shore best suited to the natural recruitment and growth of *Macrocystis* kelp.
- Sturdiness: Must be able to withstand severe storm swell activity, being submerged indefinitely, and not prone to destruction by marine animals.
- Stability: Must not pull out or be dragged to the beach by a large kelp plant.
- Recruitment: Allow the natural recruitment and growth of the original and succeeding generations of kelp plants.
- Low-Profile: Non-detectable to a casual observer (diver) once the kelp plants become established.
- Spacing: Account for the natural spacing of the plants.
- Subsidence: The recruitment portion of the anchor for kelp plants must not subside beneath the sea floor.
- Handling: Design must account for ease of handling and transport.
- Fabrication: Capable of being mass produced in a timely and cost effective manner.

The anchoring system I am proposing meets all of the above criteria. Each anchor consists of slightly more than one-cubic-foot of concrete used as the ballast portion of the anchor. The shape of the base acts to orient the anchor as it falls through the water column, ensuring its correct orientation on the sea floor after being deployed from a vessel. The similarity between the specific gravities of the cement anchor and sea floor sediment will cause the base to subside into the sediment, most likely until it is about level with the sea-floor. Once fully subsided, the pull-out strength of the anchor is increased substantially (same principle as when you get your boot stuck in the mud!).

Two strips of ultra-high molecular weight (UHMW) plastic (1” wide by ¼” thick) are keyed and imbedded into the concrete base to form arcs (Figure 9). When the concrete ballast portion of the anchor is subsided into the sediment, the arcs of plastic will protrude about a foot from the sea floor providing a surface for recruitment and growth of *Macrocystis* kelp. As the plants mature and the haptera grow down onto the sea floor, the holding strength of the system is increased even further.

Figure 9.
Proposed anchor as it would set partially subsided on the seafloor. The UHMW strips would protrude about one foot from the sea floor to provide a suitable substrate for kelp plants to recruit onto.
Robert Kiel, October 2003

The addition of a UHMW plastic sheet (1/8” thick) secured to each anchor (by running the plastic straps through it during construction of the anchor) acts as a burrow ceiling (Figure 10). This will substantially increase the ecological enhancement potential of each anchor (and subsequently the kelp holdfast) by providing habitat for an assortment of fish and invertebrates. The added cost for each anchor is nominal; the benefit to the ecosystem and the subsequent economic potential over the lifetime of the anchor would be very significant.

Figure 10.
Proposed anchor with burrow ceiling.
Robert Kiel, October 2003

The use of UHMW plastic in the anchor design will ensure the longevity of the anchor system. It is USDA certified to be non-toxic, has a high tensile strength and will not break, crack, wear out, decompose or hydrate in this proposed application. UHMW plastic is inexpensive (about $100.00 for a 4' x 8' x ¼" sheet) and easy to work with.

Succeeding generations of kelp plants will continue to grow onto the original holdfast, building up and increasing the overall holdfast size over time. I have seen holdfasts six feet in diameter and three feet tall while diving in sand-based kelp beds. If the original (dead) holdfast material is torn free from the anchor, the living kelp plants growing on the holdfast will be sent adrift but the anchor will remain for a new generation of plants to recruit onto. Because the plastic pieces on the anchors eventually become encased inside the holdfast, the forces required to tear the living holdfast free of the anchor would quite possibly be greater than that of a kelp plant growing on a rocky reef. This would enable the plants to possibly withstand quite severe swell activity without becoming dislodged.

Placement of the individual anchors would take into consideration the most favorable zone (determined by historical aerial photos) and spacing in order to obtain the greatest economy of scale and the best chance for natural recruitment and growth of *Macrocystis* kelp. The result would be the establishment of a reinforced, sand-based kelp forest capable of withstanding severe storm activity.

Kelp Anchor Design Testing:

Fabricating and deploying two dozen anchors off-shore of Goleta Bay would test the overall effectiveness of the design. This test period could take up to three years to perform. The test anchors would be spaced apart in a north-south line between thirty to fifty feet deep; within the zone where historical photos reveal the natural recruitment and growth of the kelp occurred in the past. Each anchor would be numbered and its GPS coordinates recorded. Periodic visits to each anchor would be made to gather information pertaining to the rate of settling, recruitment of kelp and other observations. A log would be kept for recording the data.

I would like to deploy the test anchors in the spring of 2004. Hopefully by the summer of 2005, juvenile kelp plants will be growing on the anchors. If the anchors prove successful at recruiting kelp, I would prefer to leave them in indefinitely to continue gathering additional information. If the anchors prove to be unsuccessful at recruiting kelp after three years, I will remove the anchors.

Applying for permits and acquiring funding for the deployment of fifty thousand or more anchors to be placed off-shore of Goleta Bay, would be contingent upon the success of the test anchors' ability to recruit and grow kelp.

Benefits of Reestablishing Sand-Based Kelp Beds:

1. Ecological enhancement of the marine ecosystem:

   Kelp forests are primary producers of food, shelter and habitat for a myriad of biota. Even kelp detritus washed up onto the beach is vital to a host of living creatures and may be a contributing factor in helping to hold sand onto the beach. Sand-based kelp beds are also less susceptible to overgrazing by grazers such as sea urchins that prefer rocky substrate upon which to live. Reestablishment of sand-based kelp beds will provide an abundant source of spores to aid in the recovery of kelp forests along other areas of the coastline. Incorporating the proposed burrow system with each anchor increases the habitat potential significantly.

2. Commercially viable resource for harvesting:

   Extractions from kelp are used in many common products in the form of additives in food, cosmetic and industrial products, and pharmaceuticals. Periodic cutting of portions of the kelp canopy for harvesting could be performed without compromising the overall integrity of the system. Performing harvesting operations may actually stimulate the growth of new kelp plants on the holdfasts because sunlight penetration to the sea floor is increased. The growth of these plants will compound the growth of the holdfast and subsequently the canopy. Reinforcement of sand-based kelp beds will help ensure their existence as a reliable resource for harvesting.

3. Possible means of mitigating shoreline erosion:

   The fast-growing nature of kelp will result in the relatively rapid recovery of sand-based kelp beds once suitable anchors are placed for recruitment. Redepositing of sand back onto the beach from off-shore would occur through natural processes. The redistribution of littoral material would likely be significant within the first year after a dense surface canopy of kelp is established. Each succeeding year would probably see less of a change with regards to ongoing widening of the beach as a new equilibrium becomes established. Seasonal narrowing and widening of the beach will continue to occur but should favor the existence of a significantly wider beach than is seen today. If tested to be effective at aiding in the formation and sustainment of a wide beach inside Goleta Bay, the same technique could be adopted in other localities as a non-invasive means of widening beaches.

Conclusion:

The reliance and dependence upon the economic and recreational use of beaches is justification for the study, refinement and implementation of systems to protect them. Examining and defining correlations and relationships which existed in the past, that were favorable to the formation of wide beaches, will help formulate strategies to recreate them.

Over fifty years worth of data is available that supports the hypothesis that the kelp bed which existed off-shore of Goleta Bay had a possible influence in the formation and sustainment of a relatively wide beach. The problem with erosion and narrowing of the beach started with the dislodgement of the kelp bed in 1982 and has precipitated with the kelp bed's inability to recover.

The implications and benefits of being able to reestablish sand-based kelp beds are significant. Testing the proposed method for the natural recruitment and growth of kelp plants on artificial anchors off-shore of Goleta Bay, will provide valuable information on its effectiveness for possible consideration in a large-scale application.

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Army Corps of Engineers:
- Coastal Engineering Research Center (CERC) 601-634-3044. Thomas Richardson, Nicholas Kraus, Joan Pope (Research and Development Center: 601-634-3034).
- Seattle: 206-764-3557. Eric Nelson.
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- Los Angeles (Civil Works Office): 213-452-3789. Tony Risco.

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Businesses Contacted:

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Pacific American Commercial Company: 800-678-6379. Randy McDonald.

Pacific Western Aerials Surveys: 805-963-0382. Michael Kambitsch.

Poly-Hi (UHMW plastic manufacturer): 360-885-1141. Dan.

Rockwell Automation: 425-746-2840. Ken Roche.

Sacramento Bag: 800-287-BAGS. Chris Marr.

Samson Rope Technologies: 800-227-7673.

Seattle Marine and Fishing Supply: 206-285-5010.

TerraSystems Inc. (Wick Drains): 540-882-4130. John Jones and Dave Panich.

The Chandlery (West Marine): 800-262-8464.

The Cultured Abalone: 805-685-1956. Dick Creig.

Wacker – High Frequency Internal Vibrators: 510-222-9790.

Williams Form Engineering Corporation (Manta Ray mechanical soil anchors): 800-344-6728.

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My interest in Goleta Beach goes back to when I was a child. Observations I have made pertaining to the changes in the beach over the years and the desire to rectify the present situation, have inspired me to write this proposal.

I was raised in Goleta since my family's arrival to the area in 1961. I continue to make frequent visits back home to visit family and friends who still reside there.

My fondness for the ocean has drawn me to interact with it in a variety of ways and pursue knowledge about its many wonders.

I graduated from The California Maritime Academy in 1981 where I received a degree in Marine Engineering.

My wife Kelley and I have lived in Seattle since 1982. We have two children (Justin - 14 and Jessie - 11) who keep us very busy.

I have been employed at the Seattle Aquarium since 1987 as the Chief Systems Operating Engineer.

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